52 Processes and Automation in Dairy Industry

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The objectives of this chapter are the following:

1. Understand the principles of dairy process
2. Study the important aspects of dairy process control
3. Appreciate benefits of automation in dairy

Food and dairy industry is becoming one of the major backbones of the development of world economies. The growing demand for the food and dairy products due to population and nutritional awareness has resulted in enhanced production cycle. The dairy industry is looked like the support business for farming. The livestock of cattle and buffalos mainly contribute to the variability of the input. The dairy industry is mainly run by cooperative societies and the farmers are primary stakeholders. Due to globalization and competition from other sectors, this industry is also witnessing changes. This change is, in many folds, in the operation of the plant. Use of modern equipment and sensors is becoming common. Areas of automation in dairy industry are identified by many manufacturers, which will boost the efficiency of the plant. The production downtime is a major issue as the commodity is perishable one.

NATURE OF DAIRY INDUSTRY

The dairy industry is mainly seasonal and divided in flush and lean seasons. Due to the perishable nature of the commodity, the processing of the raw material is of utmost importance. The raw milk from the collection centers is transported to the dairy using tankers. The variability in raw milk is mainly due to nature of farms. An instrumental analysis of the milk at the collection center can only reveal the quality of the milk. The shelf life of the milk is required to be enhanced; hence milk processing in dairy becomes inevitable.

Evolution and Progress of Dairy Industry

It is reported that the first goats were domesticated around 7000 BC in Iran, and cattle a little later, around 6000 BC in Greece. It is not certain when humans first started milking their domesticated animals. One of the earliest milking scenes in existence today, which shows a goat being milked, is on an Elamite seal from 2500 BC. Today, dairy industry is becoming very influential due to the support mechanism generated for the farmers as a side business for farming. The policies of the government with respect to price support and distribution networks are influenced largely by these industries. The large amount of artificial additives through antibiotics and other chemicals through the feed has made this business controversial.

Products in Dairy Industry

Products made from milks are:

- *Cheese*: It is made by allowing milk to ripen or sour. Then the lumpy curds are separated from the liquid whey by adding a coagulant such as rennet. The curd is then cut, heated, strained, pressed, and aged. Cheese is rich in protein and fat, and most cheeses contain good amounts of calcium, phosphorus, and vitamin B2 and vitamin A.
- *Butter*: Butter is churned from cream. In the past, this was done by skimming the cream off the top of the milk and hand-churning until it is separated.
- *Butter milk*: Traditionally, buttermilk was the liquid left in the churn or drawn off as the butter formed. It contains more protein, calcium, and vitamin B2.
- *Cream*: Cream is that part of the milk, which has the highest percentage of butterfat. Whole milk usually has 4%–5% butterfat, it depends on the individual cow and on the breed.
- *Whey*
- *Yogurt*
- *Other Products produced by dairy industry, such as*
  - Pasteurized milk, flavored milk, reconstituted milk
  - Cream
  - Butter/ghee
  - Ice cream
  - Yoghurt, curds, and buttermilk
  - Cheese, paneer, khoa, and others
  - Condensed milk
  - Milk powder, dairy whitener, etc.

SPECIALITIES OF DAIRY PROCESSING

There are a number of special requirements in handling milk and milk products due to short shelf life and being prone to getting "spoilt" or unfit for human consumption. Therefore, the industry observes the following:

1. Use of stainless steel as material of construction (MOC), having the following:
   a. Highly polished surfaces
   b. Special fabrication and construction
   c. Special end connections to avoid stagnation of milk in nooks and pockets
2. High cleanliness requirements, clean in place (CIP) systems
3. The need to increase shelf life for better supply and distribution
4. Aseptic processing and aseptic packaging

AUTOMATION IN DAIRIES

The main processes involved in dairy plant are as follows:

- Milk collection center and quality check at factory gate
- Milk reception section
- Pasteurization section
- Pouch filling
- Evaporator
- Spray dryer
- Cream pasteurization system
- Butter making section
- Dispatch section
- Utilities like boiler, chillers, compressors, hot water, etc.

Milk Collection Center and Quality Check at Factory Gate

The milk that is collected at various points from the farms is being dispatched through cans to the central collection unit. As milk is perishable, care is taken to maintain the temperature during transport. The cleanliness of the cans is most important activity and done after every dispatch. Hot water rinsing and caustic wash are preferred for cleaning. After the milk is received at the collection center, the following steps are followed before further processing:

1. The cans are transferred to conveyor belts.
2. After cleaning of the plunger, the sample is taken from cans.
3. Organoleptic and CoB tests are carried out for the adulteration.
4. For suspected adulterations, sedimentation, sugar, and soda tests are conducted and if the test is positive, the milk is safely destroyed.

Milk Reception Section

After the milk is received at dairy through tankers, further processing for the raw milk reception is carried out. The schematic of raw milk section is as shown in Figure 52.1. The milk from the collecting point is taken through tankers to the factory. After the gate clearance, a hose is connected to the tanker and milk is taken to the filter through deaeration. The pumped milk is stored in an intermediate tank after metering. The metering is done either through a weigh bridge or a flow meter. At every stage, care is taken to ensure cleanliness of the hose and pipe lines. If milk is to be stored overnight, it is passed through deep chilling or pre-chilling at 10°C. This is carried out through a milk chiller as shown in Figure 52.1. The chilled milk is then stored in raw milk silos. This section is typically called as milk reception section.

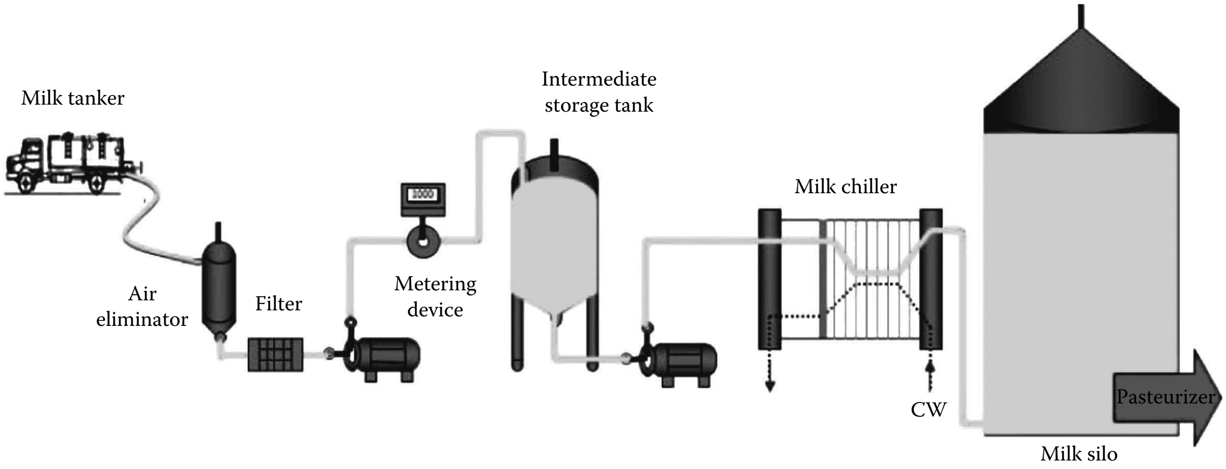


FIG. 52.1
Processing of raw milk at the reception section.

Pasteurization Section

The milk needs to be preserved for extra time; hence the pasteurization is mandatory. The pasteurization process flow diagram is as shown in Figure 52.2. The milk from the raw milk storage is taken to the balance tank for temporary storage. Prior to that, fat contents and solids non fat (SNF) is tested and if required the adjustment is done by adding cream or skimmed milk. From the balance tank, milk is pumped to plate heat exchanger (PHE) at 4°C and heated up to 50°C in regenerative section. The hot milk is then taken to centrifugal separator wherein the cream is separated from the milk to be processed further through PHE, heated up to 68°C. The cream produced in centrifugal processed separately. The hot milk at 68°C is then passed through homogenizer and the floating particles are mixed in the milk at high pressure and speed. The homogenized milk is then passed through the heating section of the PHE and the temperature of the milk is raised to 78°C. It is the requirement of the pasteurizer that the milk should be kept at 78°C for 15 s, hence the milk is held through a holding coil as shown. The milk is then transferred through the regenerative section and after a cooling section wherein it is chilled at 4°C. In certain cases, the milk is needed to be passed through deep chilling at 2°C for enhanced storage time.

Pouch Filling

The milk is required to be sold in the market through pouches. The scheme of the pouch filling section is as shown in Figure 52.3. The pasteurized milk is first taken to a storage tank above pouch filling machine. Depending on the size

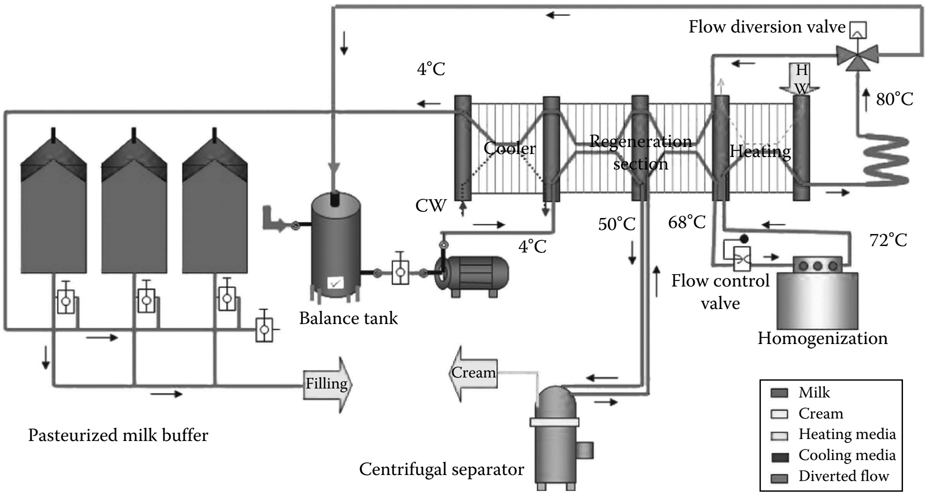


FIG. 52.2
Processing of milk at the pasteurization section.

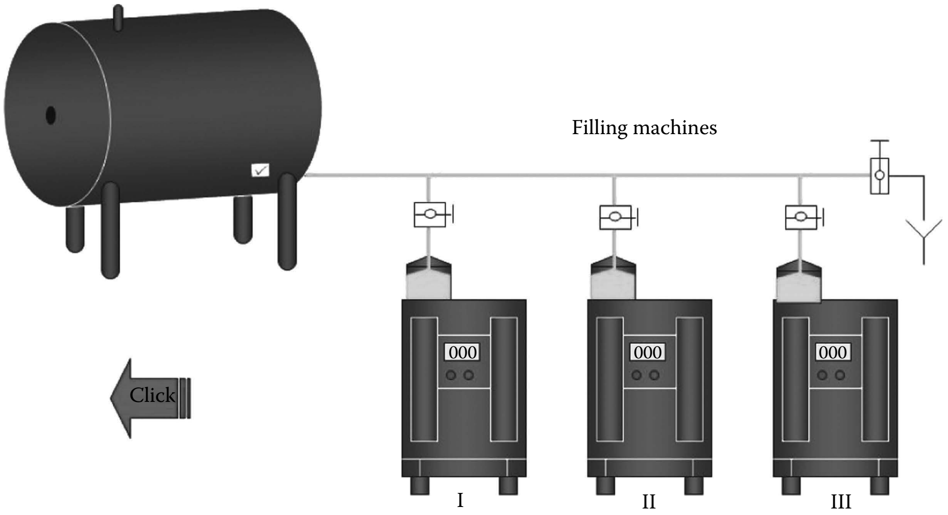


FIG. 52.3
Processing of milk at the pouch filling section.

of the packing requirement, the machines are selected to fill the milk and seal the pouches. The weights and leakages of the pouches are confirmed on random basis. The faulty pouches are stored and used again through raw milk silos. The leak proof pouches are taken for loading in crates. It is further conveyed to insulated room and then taken for dispatch section.

Cream Pasteurization System

The cream produced using the centrifugal separator is collected in balance tank for cream pasteurizer cycle. The cream is transferred using feed pump for heating through holding coil and the temperature is maintained constant for 15 s. The hot cream is then cooled at stage I and II using tower water and chilled water as shown in Figure 52.4. The chilled cream is stored in ripening tanks. After the process of ripening is over, it is taken to butter section.

Butter-Making Section

In butter-making section, the pasteurized cream is transferred to butter-churning machine. The butter is separated and the butter milk is stored for further processing. The butter produced by churning is transferred to butter-packing section with the help of butter trolleys as shown in Figure 52.5. The butter-packing machine takes care of weight and packing of the cubes for dispatch section.

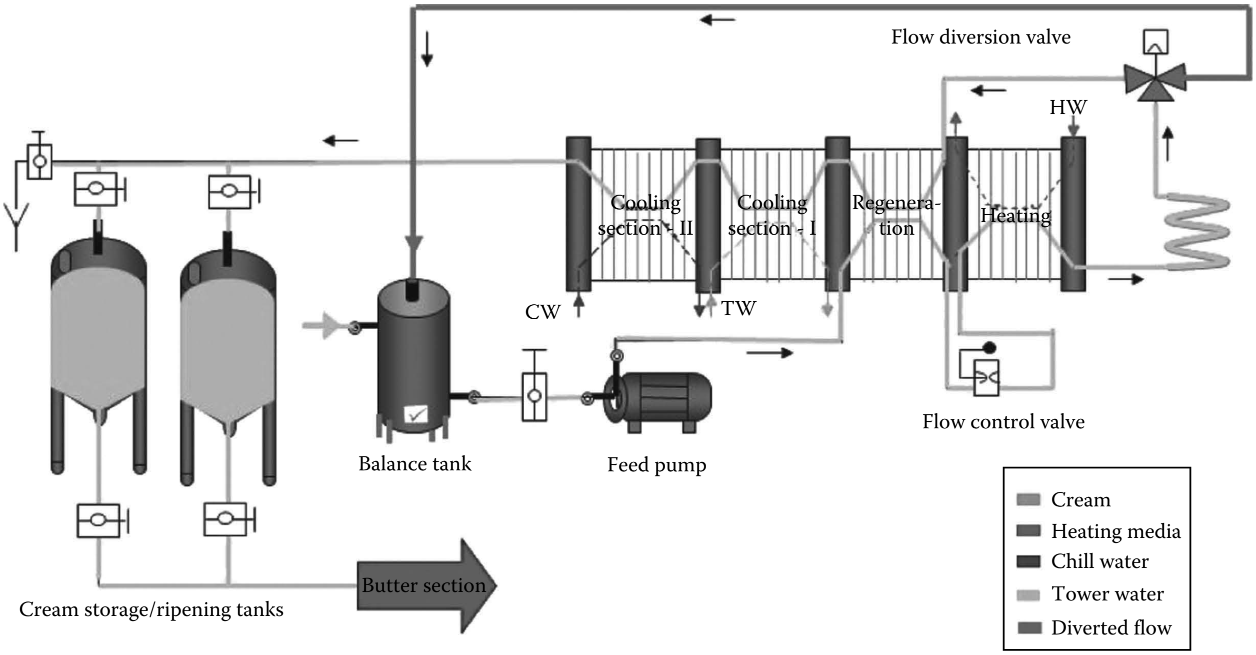


FIG. 52.4
Processing at the cream pasteurization section.

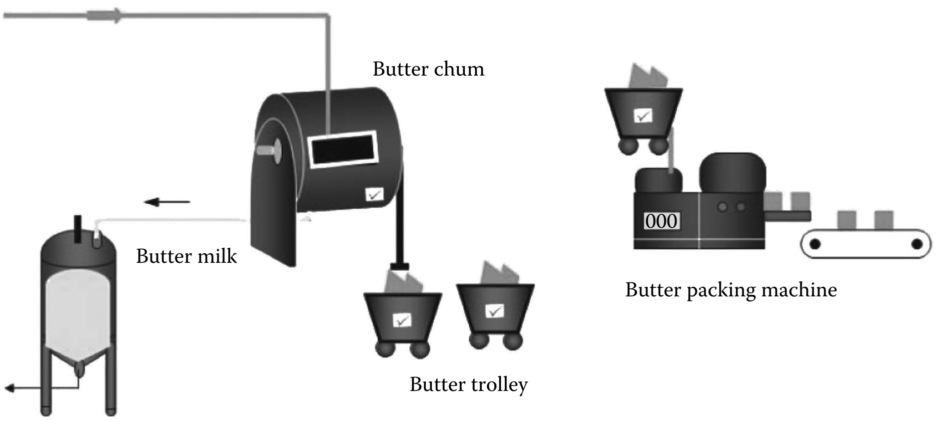


FIG. 52.5
Processing at the butter making section.

Hot Water Generation Section

For many sections like pasteurization and cleaning of the vessels, hot water is required. The hot water is produced using a tubular heater as shown in Figure 52.6. The normal water enters the tubular heater and the steam is passed in opposite direction. Due to heat transfer, the temperature of the water increases as per the requirement and the same is used in the plant for various purposes.

Common requirements for the dairy process are as follows:

- Sequential, batch, short continuous, or semi-continuous operations with integrated CIP cycle
- Many alternative paths since cleaning is mandatory at the end of each operational or processing step
- Selections of feed supplying tanks, product tanks, processing lines, packing lines
- From subzero temperatures (e.g., ice cream) to boiling and beyond (e.g., milk powder)

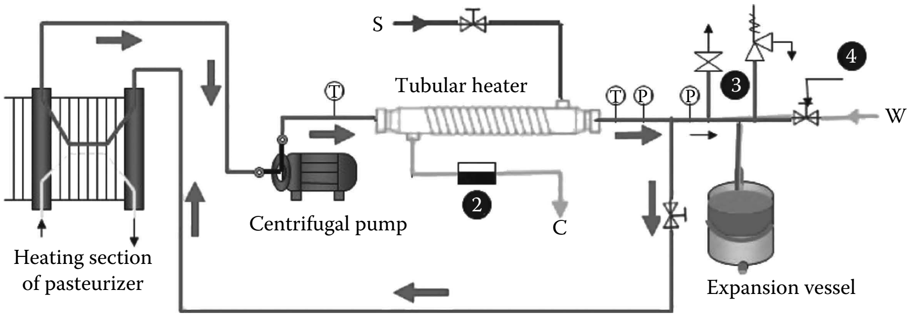
HMI AND AUTOMATION IN DAIRY INDUSTRY

The operational efficiency needs to be improved in any plant by reducing manual intervention. Hence, the operator needs to be given interface to smoothly operate the plant through HMI. The parameters like temperature at critical points, interlocks to ensure sequencing of processes, and quality checks thorough analytical instruments at all strategic locations are captured for the operation of the dairy. Many areas can be identified for automation in dairy industry; a few of them are listed below:

- Refrigeration section
- CIP
- Milk pasteurizer
- Boiler
- Evaporator
- Spray dryer
- Packing section

Automation Benefits

Typically, automation benefits can be listed in light of plant uptime, and eliminate manual reporting efforts through log books. The alarm feature available in majority of the automation tools makes troubleshooting easy and focused. Majority of the dairies are now semi to fully automatic. The extent of automation depends on the competency of man power available, support from the manufacturer, and cost of automation. The benefits of automation can be viewed in terms of energy conservation in utilities like refrigeration, air compressors, water supply and distribution, boiler, and effluent treatment plants. The same can be observed in production cycles of dairy. The major impact is seen in reporting mechanism. Currently, the log books are replaced by the trends and electronic data processing tools, which are integral part of the automation. Online or offline data analysis has made significant contribution in decision making and enhancement of the quality of milk products. As mentioned previously, the shelf life of the product bears the utmost importance. The processing techniques supported by time stamping of data made it easy for the dairy owners to take stock of the situation and apply necessary corrections to improve upon the performance. Accurate control through PLC and time settings for sequencing operation derived key benefits of automation. Safety interlocking is used to avoid jams, spillage, and wastage. Complete supervision of the production cycle is possible from any location due to automation and this has resulted in major aversion of breakdowns. It has been observed and reported that the overall efficiency and productivity is improved due to automation.



1. Steam shut-off valve
2. Steam trap
3. Safety and vent valve
4. Water regulating valve

FIG. 52.6
Hot water generation for processing milk and milk products.

FUTURE TRENDS

The pace at which technology is progressing, the dairy industry is also performing better. The next-generation dairy industry will be decentralized, smart, responsive, and remotely monitored. The intelligent systems will start playing an important role in the domain knowledge availability even at field locations. Integrated architecture of automation and unified command through seamless data availability will be the path for tomorrow.

Acknowledgments

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